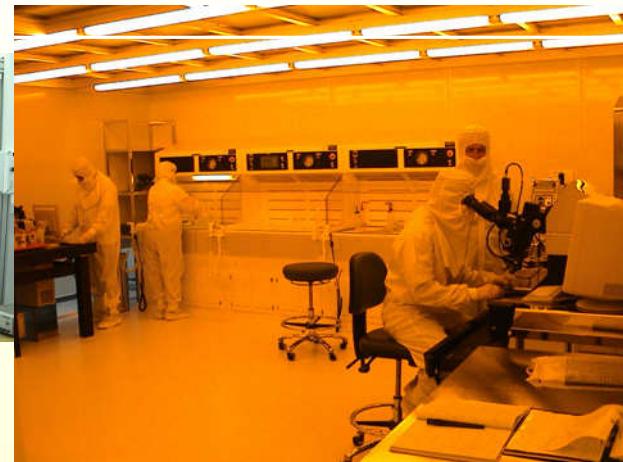


Room Temperatures Quantum Nano Engineering:



[Yossi Paltiel \(QSIP 2009\)](#)

*Solid State Physics Group, Soreq NRC, Israel
Applied Physics Department and Nanotechnology Center,
Hebrew University, Israel*

האוניברסיטה העברית בירושלים
The Hebrew University of Jerusalem



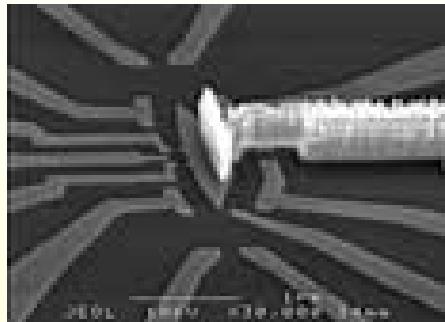
Content Summary

- Why nano?
- Self assembled dot
- Self assembly studies and drawbacks
- 3 slides on our new nano quantum engineering tool box
 - Nano crystals
 - Organic molecules
 - Nano metal particles
 - Plasmonic antennas

Why Nano and Meso?

Use and Study Quantum effects in the world of high temperatures (300K)

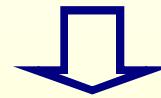
E-beam 2DEG



- **Low Temperatures**

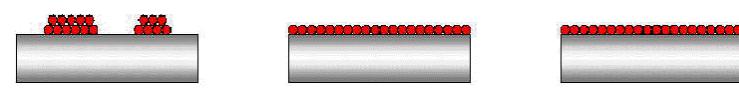
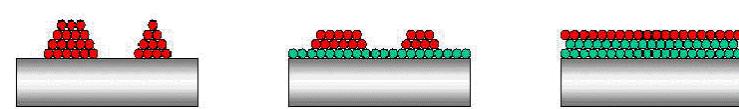
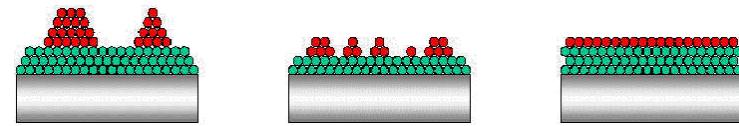
Big dots (larger than 30nm), 2DEG density fluctuations

- **No Scaling for many dots**, E beam lithography



Moti Heiblum Weizmann

Self assembly



(a) V-W

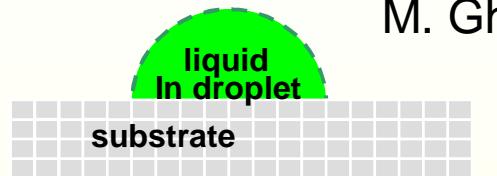
(b) S-K

(c) F-vdM

Droplet Heteroepitaxy

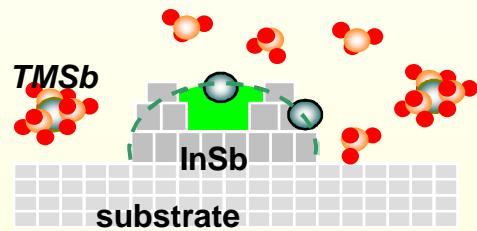
A method which allows great flexibility in substrate/dot materials combination,

M. Gherasimova et al. APL 85 2346 (2004);



First stage of the growth:

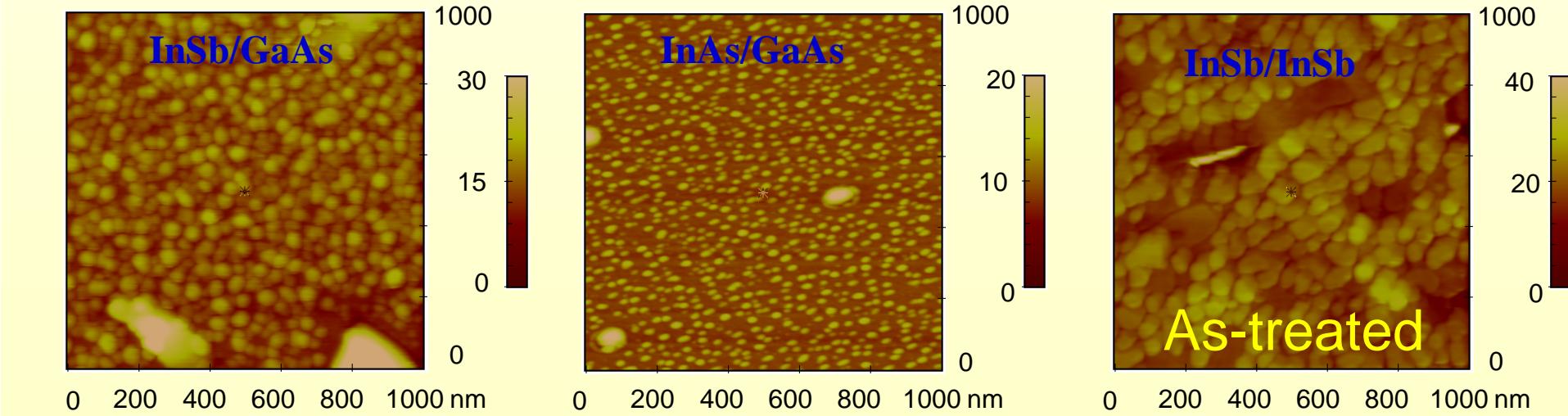
group III element nano-droplets formation on the substrate



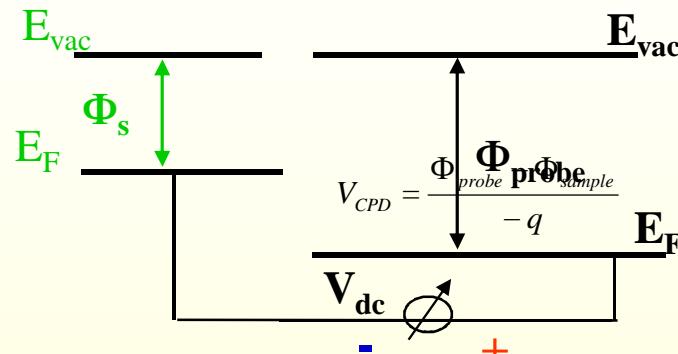
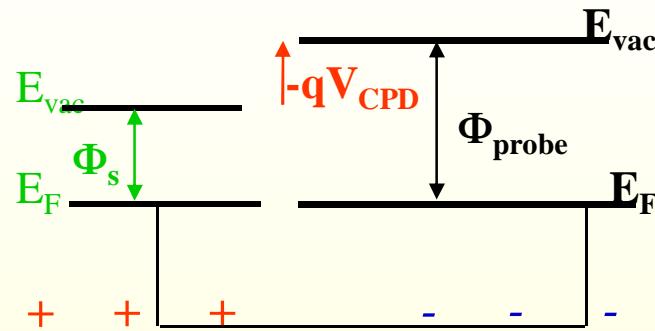
Second stage of the growth:

reaction of these droplets with one or more group V elements
in the gas phase for III-V nanocrystal formation

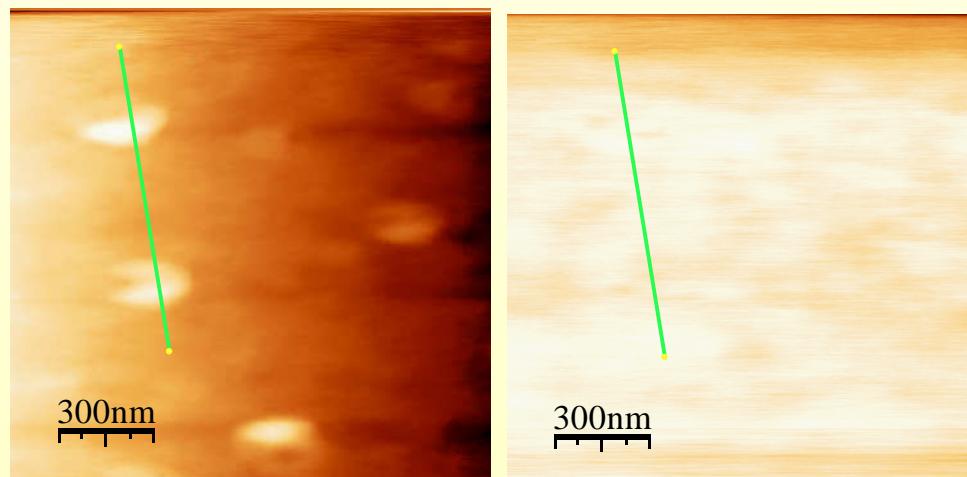
journal of Crystal growth 2006



Contact potential difference (CPD) measurement using KPFM



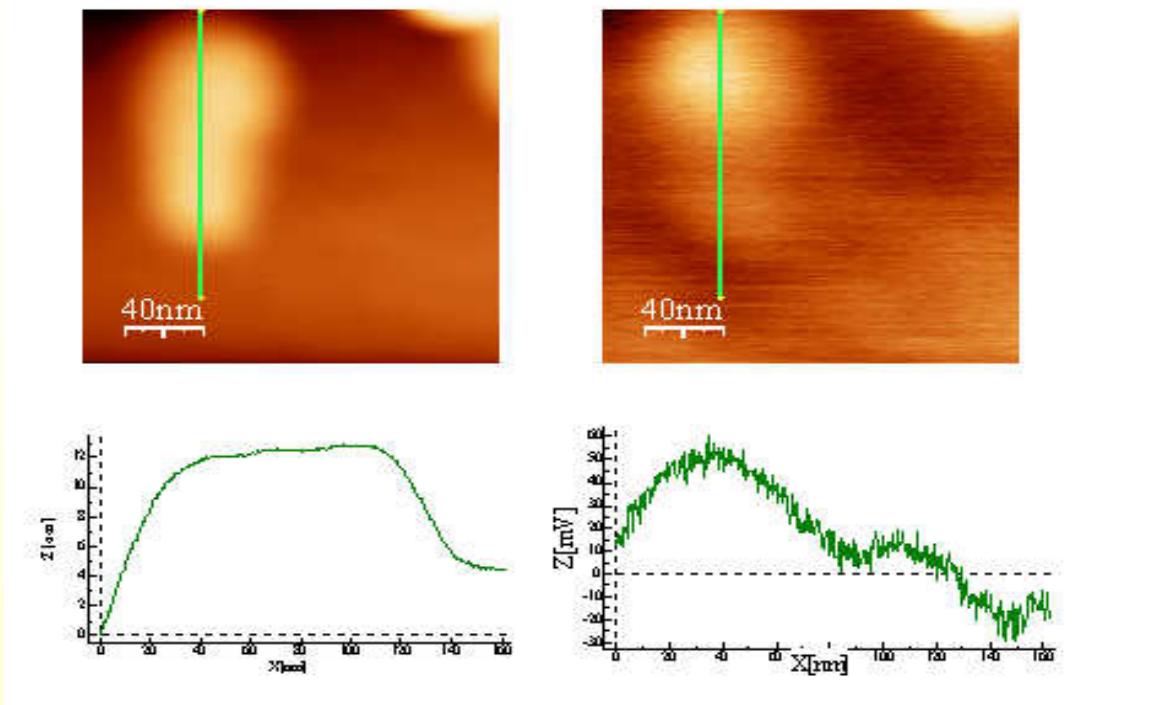
InSb nano-dots on InSb



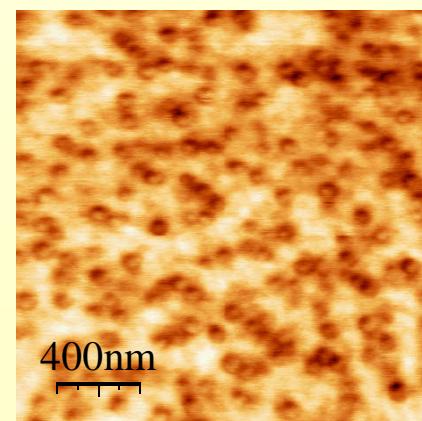
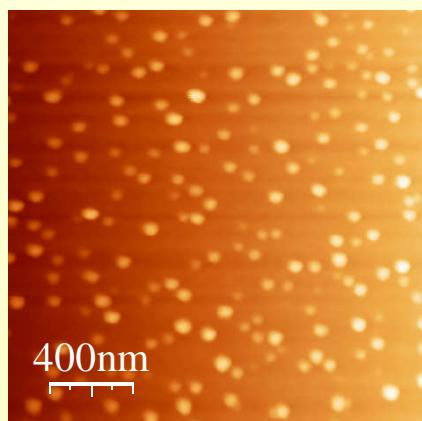
Topography

-CPD

Energy levels inside the dots

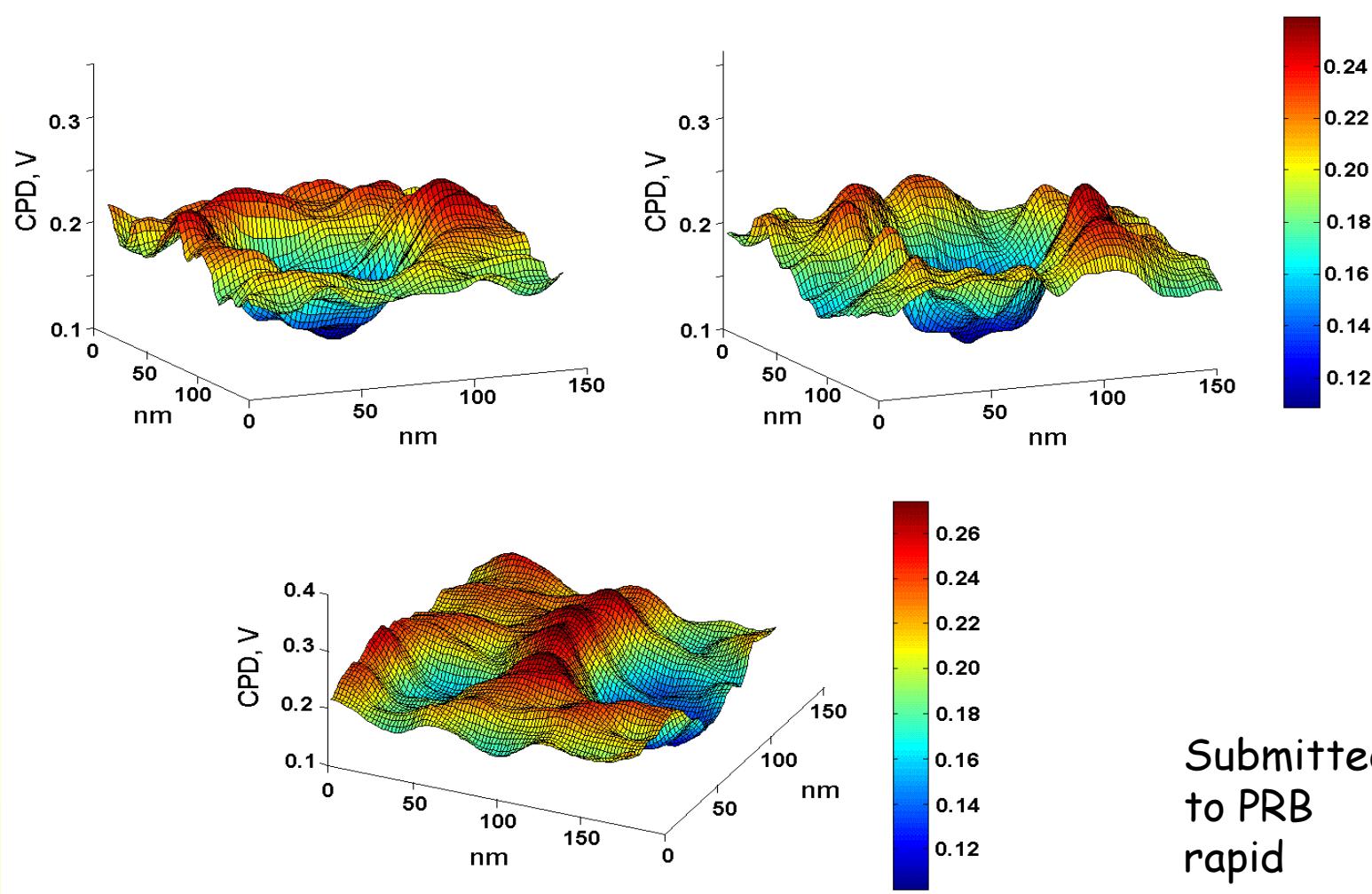


InAs/GaAs



Nanoletters 2007

Self assembled nanodots work function mapping

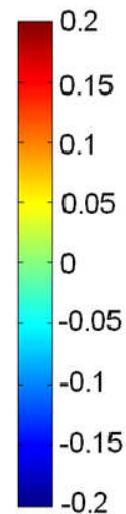
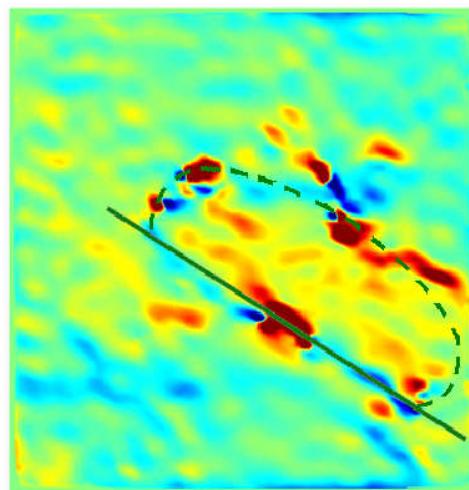
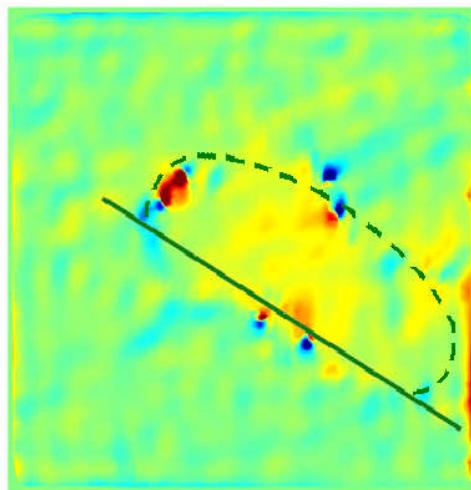
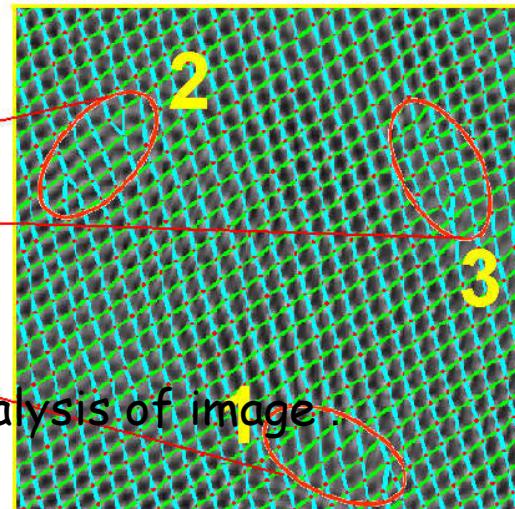
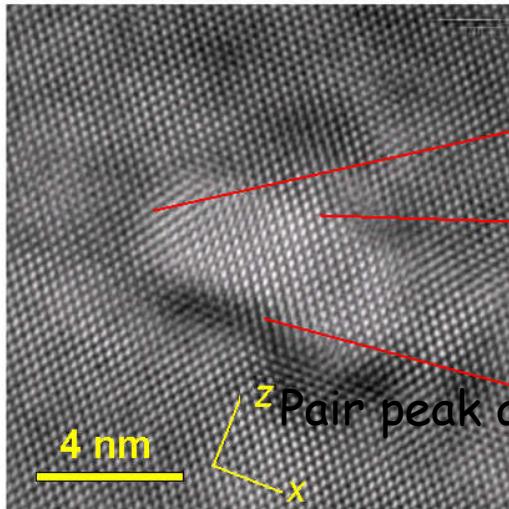


Submitted
to PRB
rapid

TEM dislocations

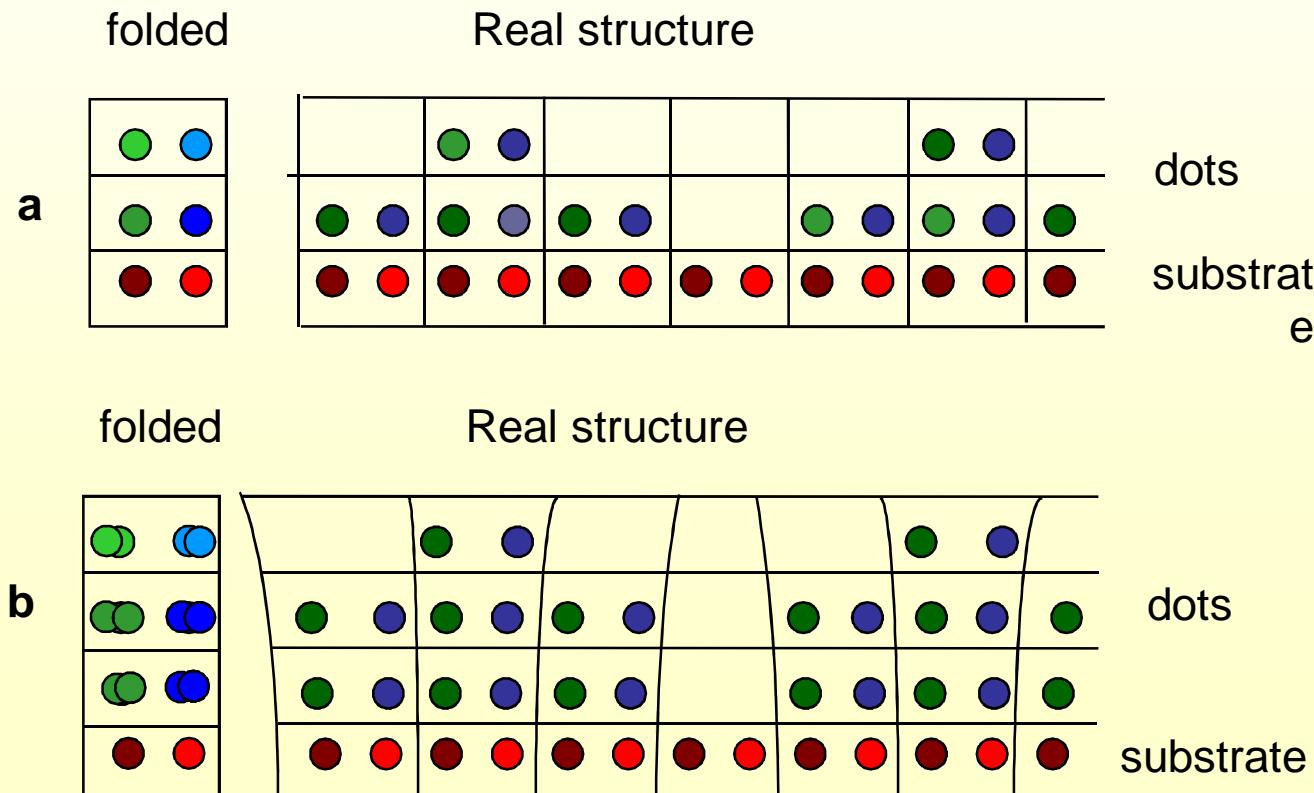
TEM cross section in [110] plane of InSb quantum dot grown on GaAs and capped with 70 nm thick GaAs layer

Pair peak analysis



Coherent Bragg Rod Analysis (COBRA)

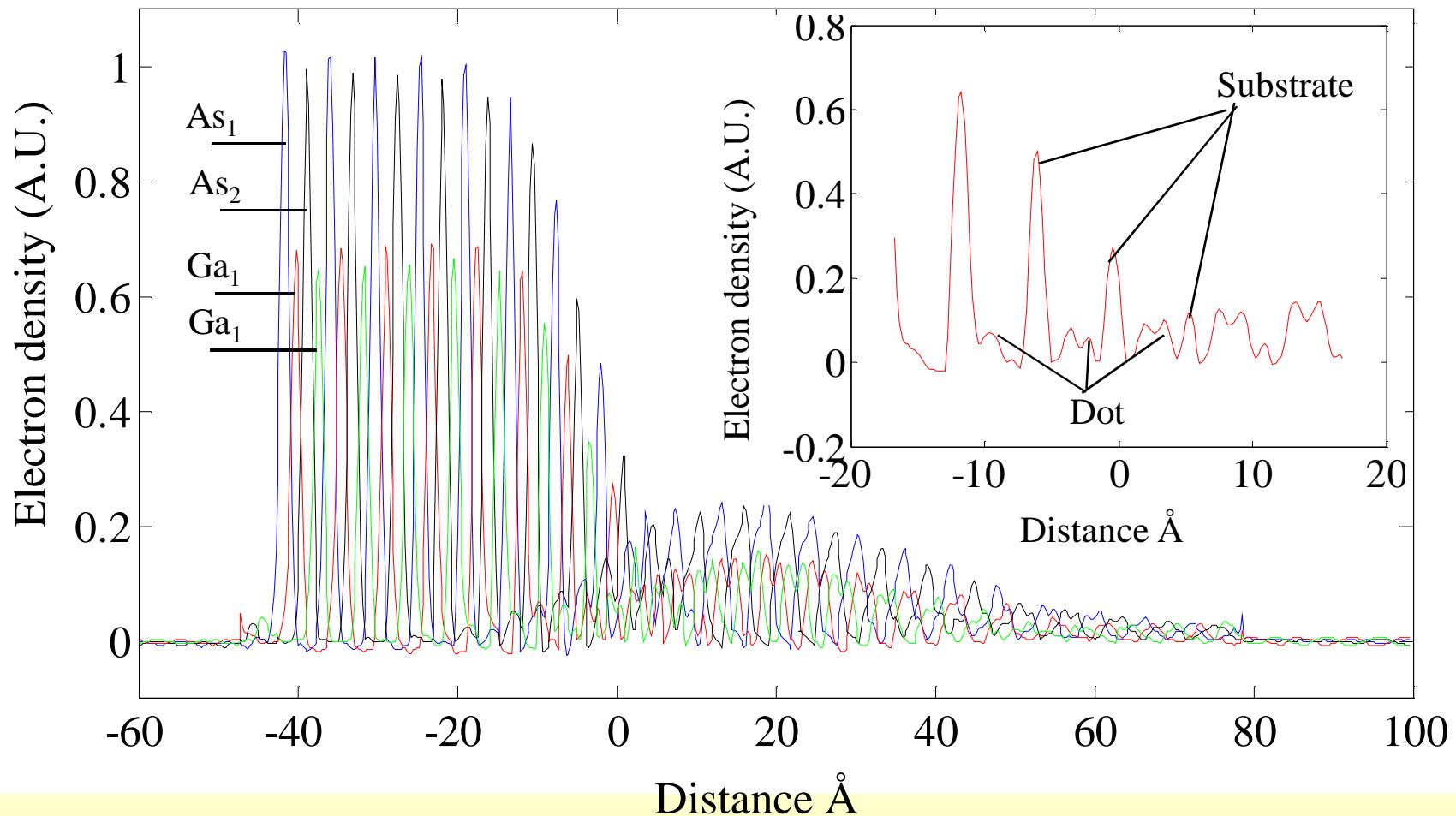
- X-ray diffraction intensities along the system Bragg => calculate the diffraction phases.
- Fourier transforms the resulting complex scattering factors => 3D real space electron density
- The resulting electron density provides the atomic structure with sub-Angstrom resolution.

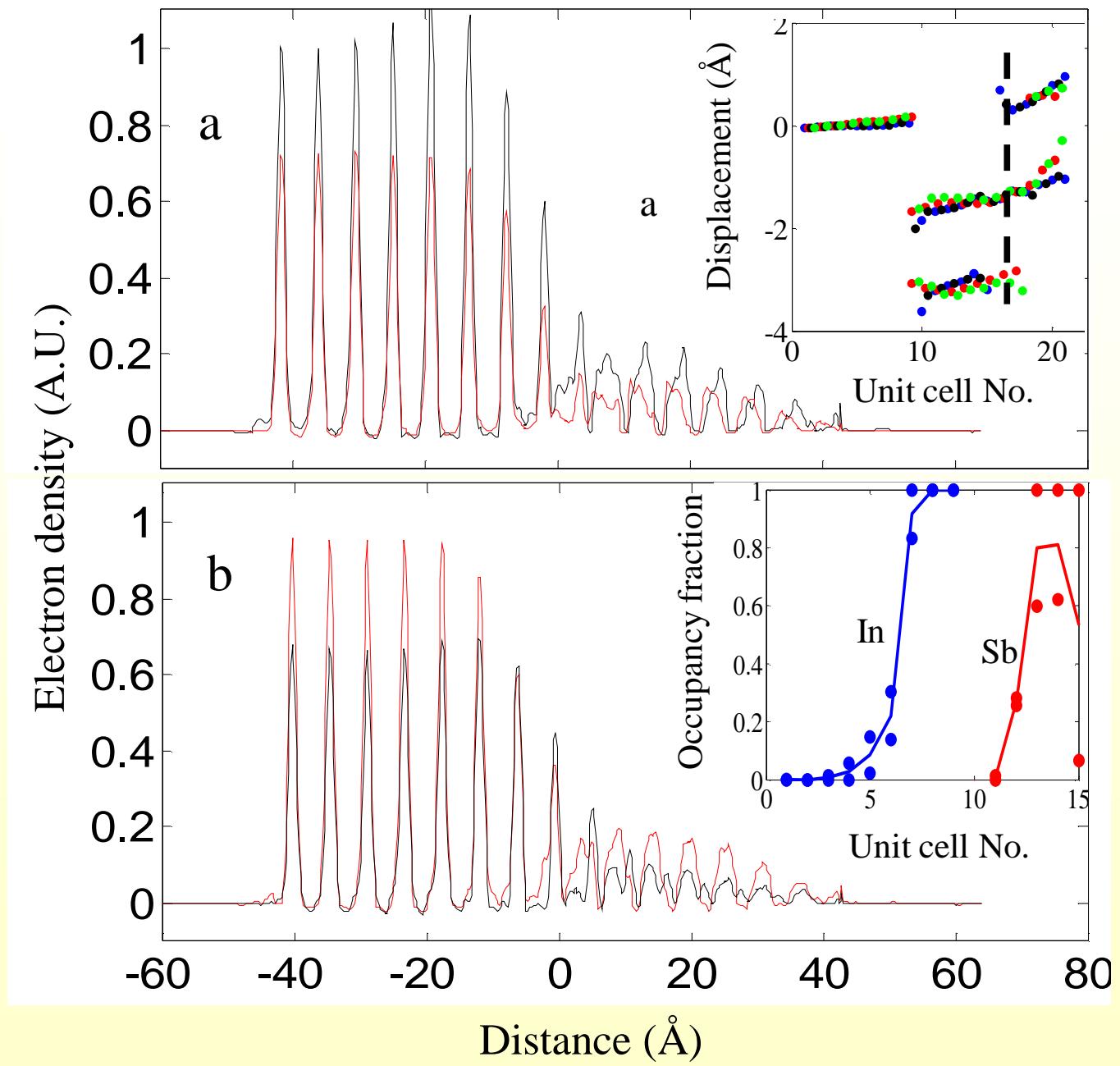


Coherent Bragg Rod Analysis (COBRA)

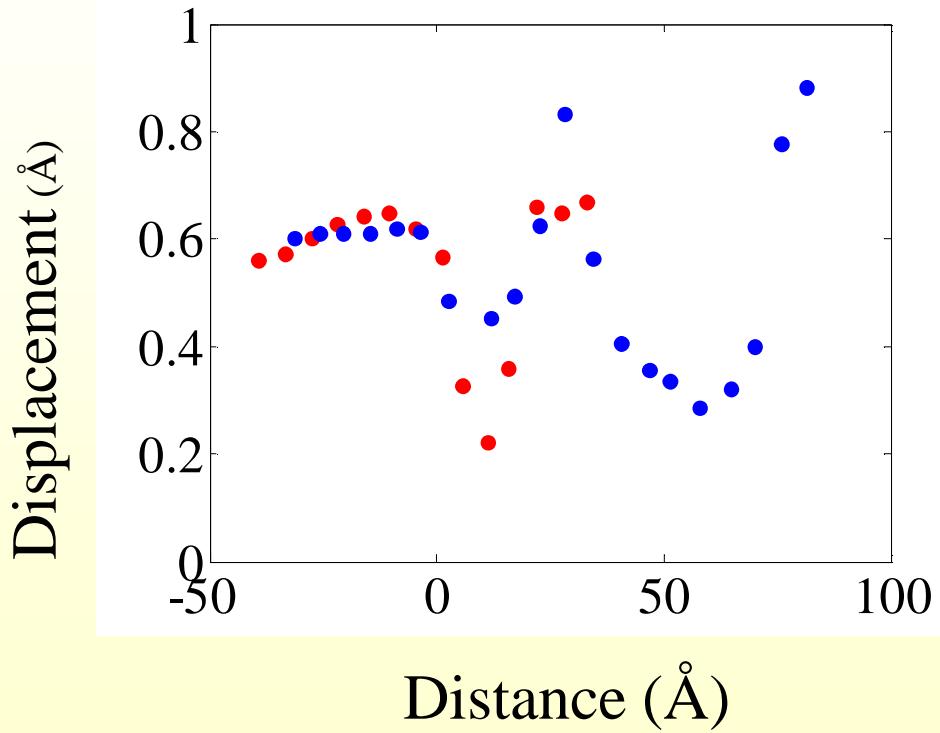
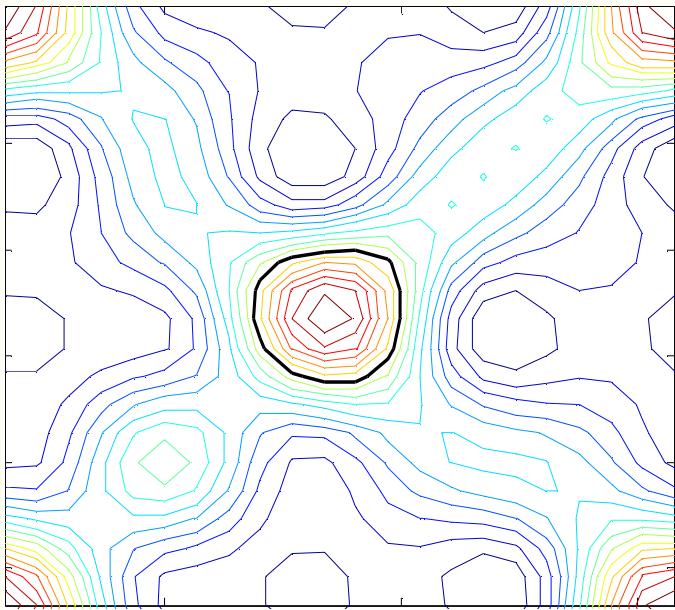
The method uses measured x-ray diffraction intensities and phases along the system Bragg rods to calculate the electron density in a layer.

Submitted to nature nano

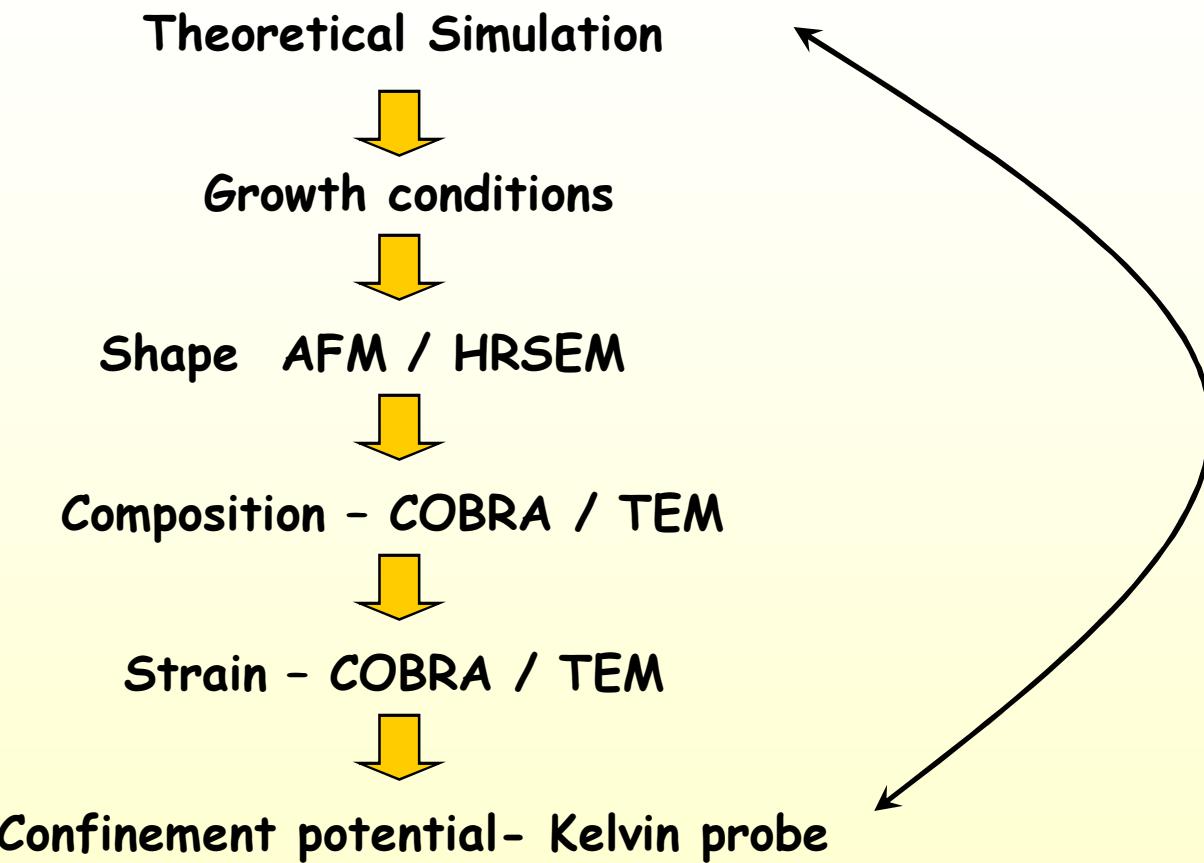
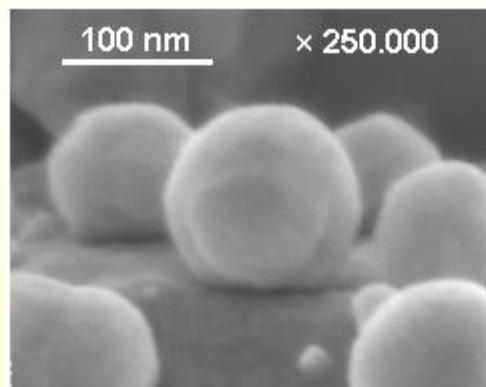




Lateral displacement and Strain



Self assemble



Maybe not enough!!!

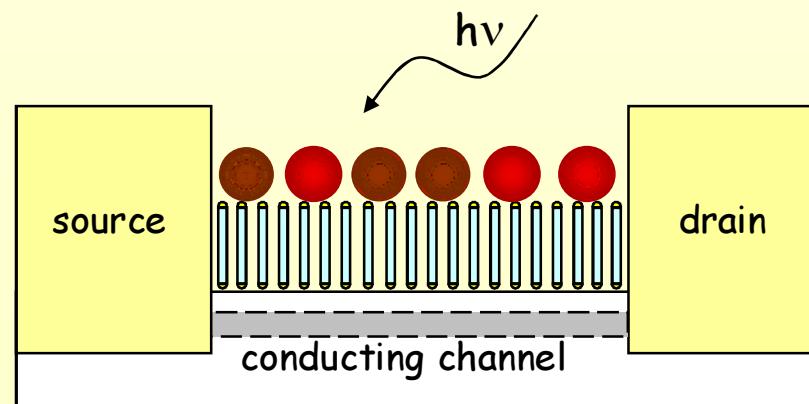
With self assembled dots the confinement potentials is not controlled

One other solution

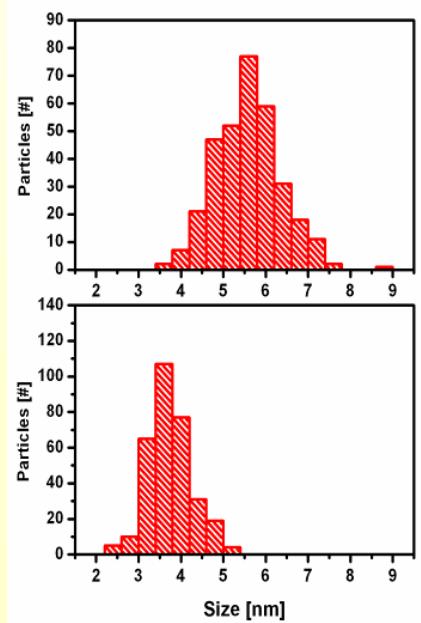
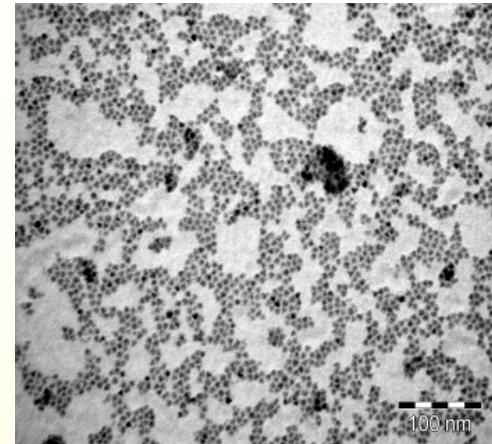
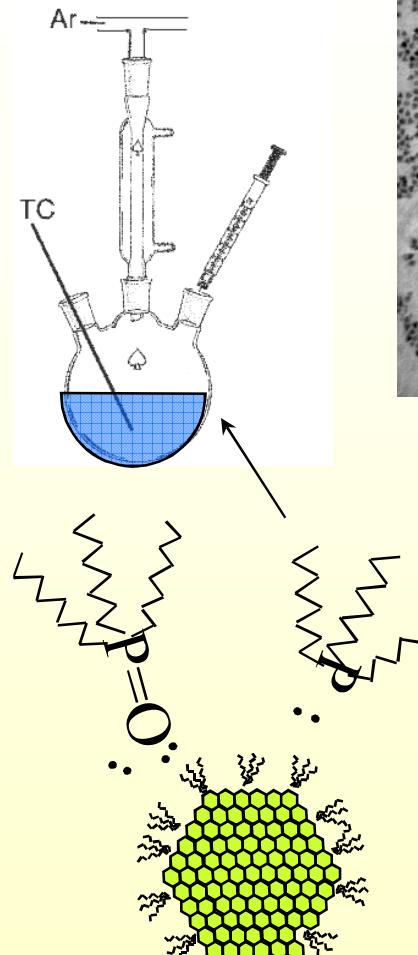
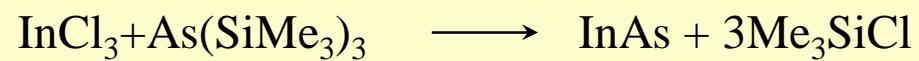
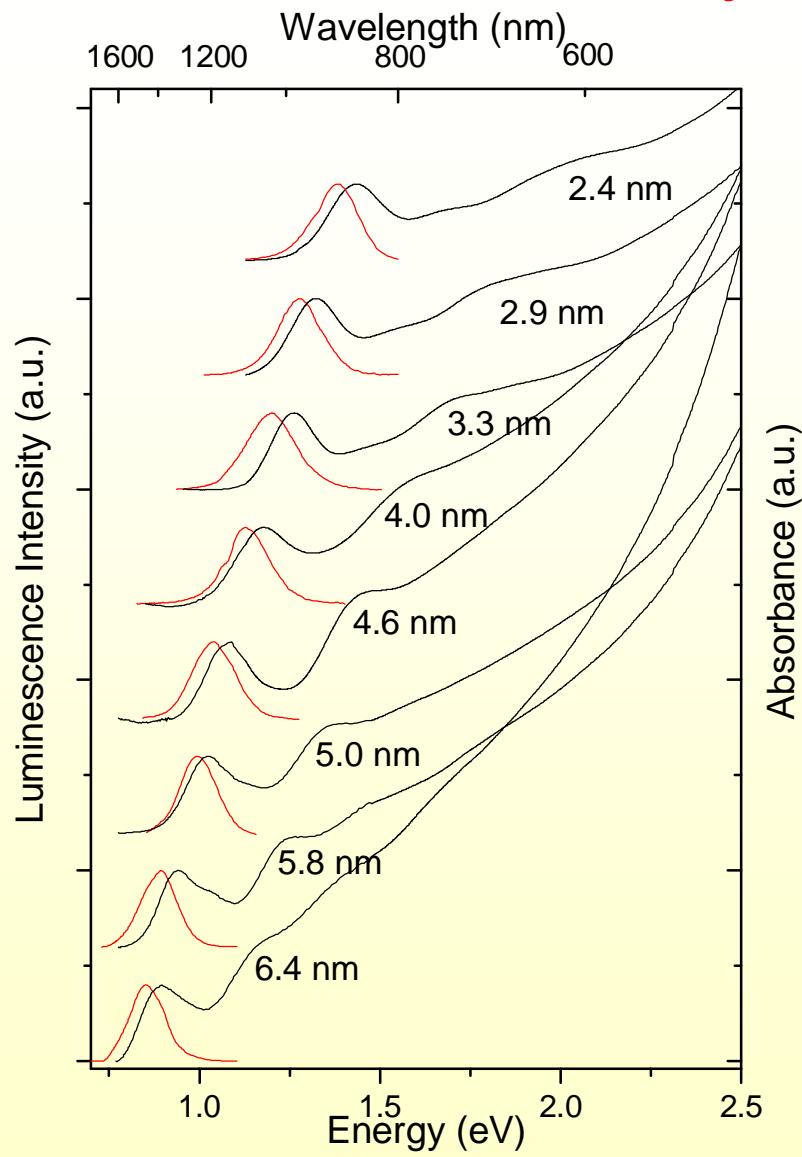
Goal: To develop Room temperature controlled quantum physics and devices

Controlling the nanodots: size, energy levels, coupling and the doping.

Building nano tool box which include
nano crystals, organic molecules, metal nano particles,
enables controlled coupling to the environment

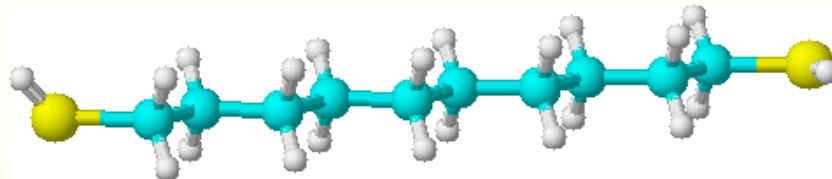


Nano crystals chemistry



coupling control with organic molecules

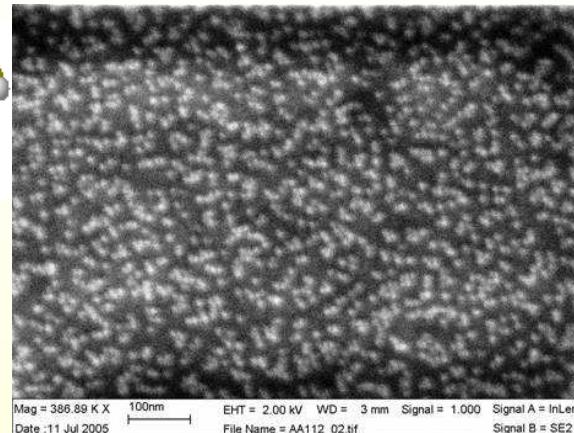
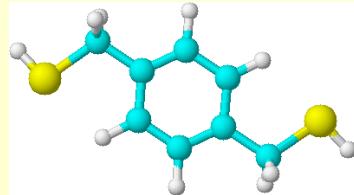
The molecules used



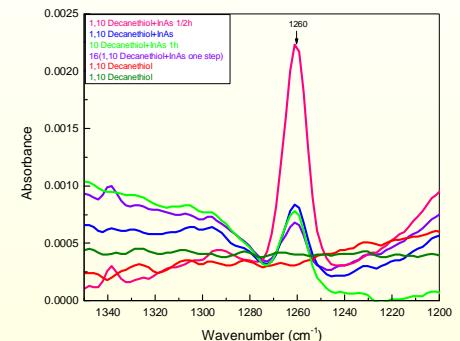
HS-(CH₂)₁₀-SH DT

HS- (CH₂)₂-SH EDT

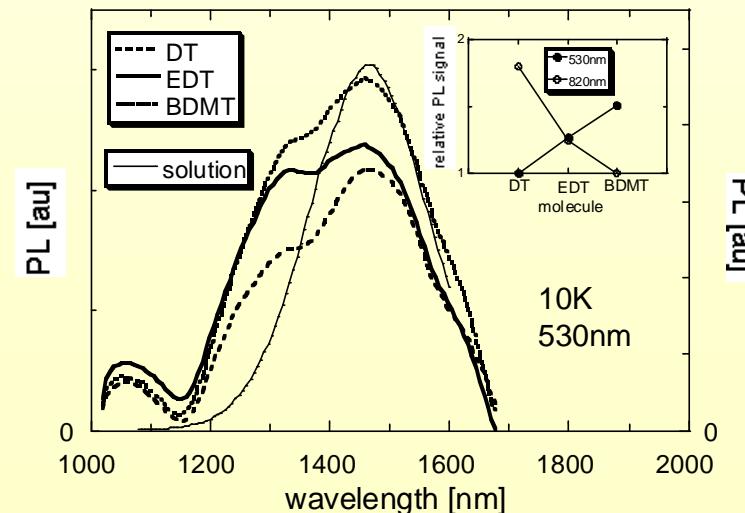
HS-CH₂-φ-CH₂-SH BDMT



CH₂
Vibration
mode



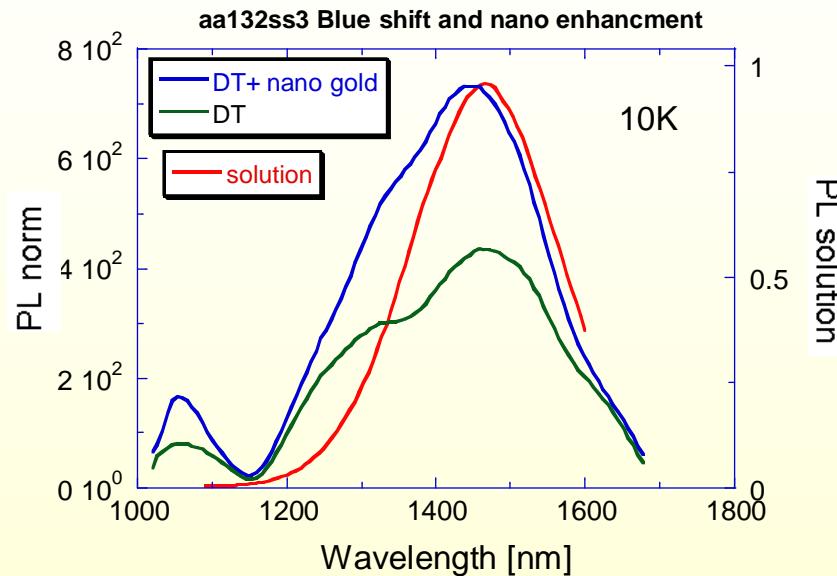
SEM picture of connected InAs nanocrystals



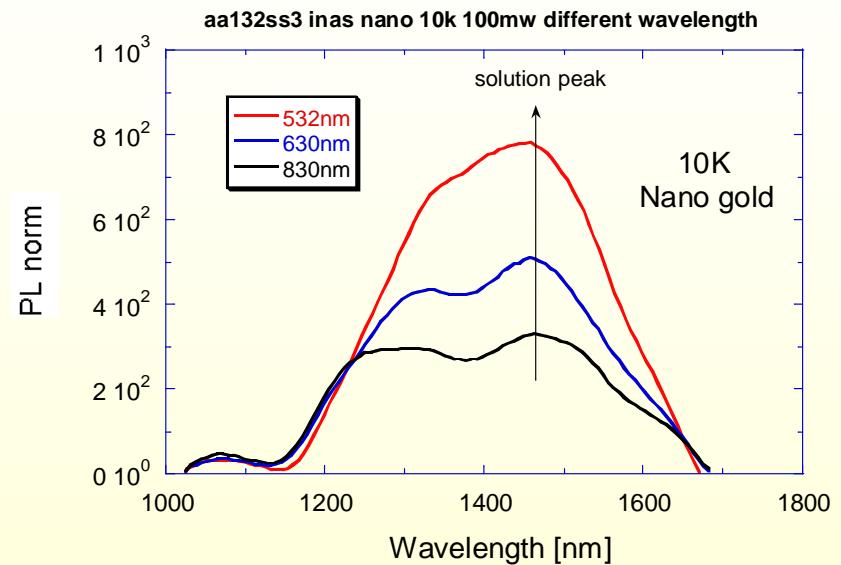
APL 2006

Nano gold particles - local field enhancement

With and WO the nanogold



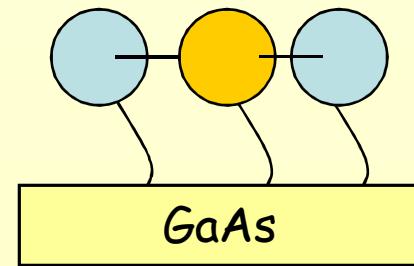
Local field enhancement



Building new molecules combined with metal nano particles and semiconductor nano

Future work:

Building artificial molecules with local field enhancement
Nano plasmonic affects

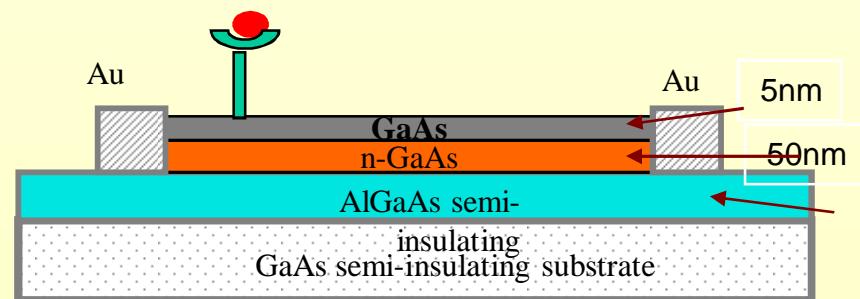
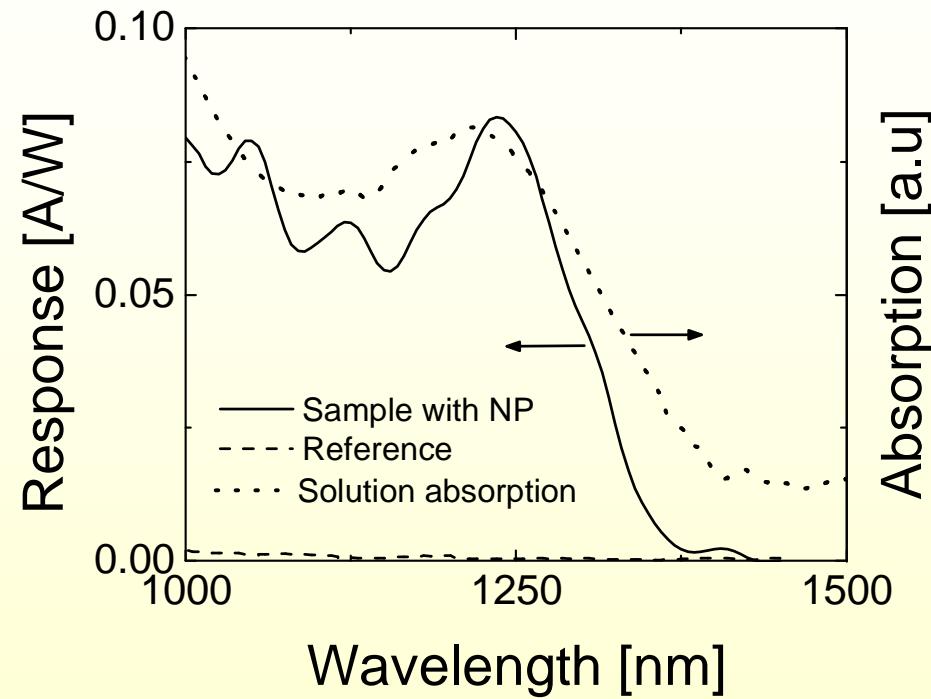
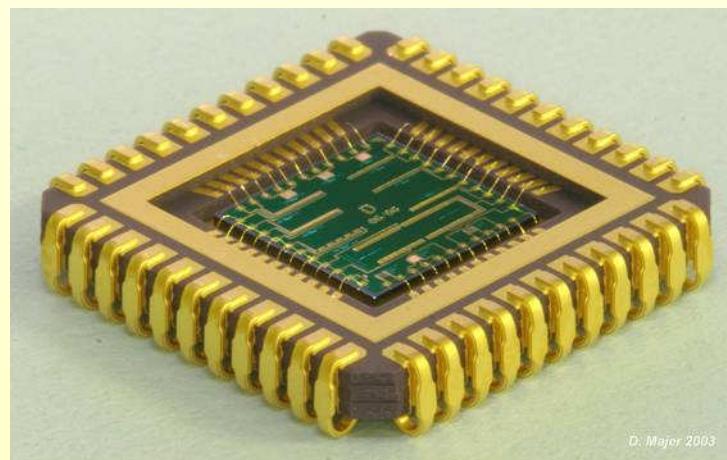
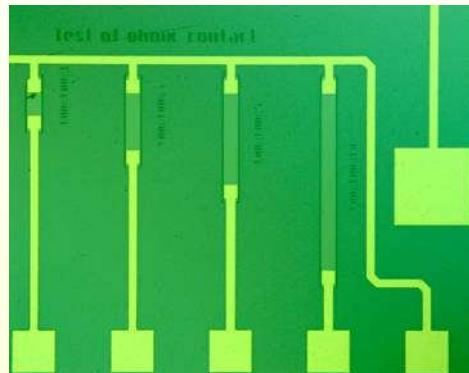


APL (2006)

Example: Hybrid quantum light detectors

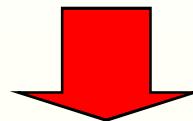
APL (2008)

FET transistor with Sb based nanodots acting as a gate



Where can we go from here?

We have efficient Nano toolbox !!!



- Nano - environment coupling control and study using transport, optical ad noise measurements.
- Plasmonic devices and physics
- Spin control with the molecules, spin coupling
- Single photon detector and emitter at room temperature
- Single electron transistor at room temperature
- Optical memory
- Quantum non binary logic in room temperature



Summary

- Nanodots and nano crystals open a way to achieve very sensitive high temperature quantum physics.
- Our coupled controlled system gives the opportunity to study the limits between quantum and classical physics
- We are creating a novel device methodology for constructing complex circuits of quantum nano-devices